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Work by Nathaniel Durlach and his collaborators is summarized here

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RESEARCH ON REDUCED CAPABILITY HUMAN HANDS

Highlight

Recent work conducted with human hands degraded by mechanical constraints has led to results that are consistent with the results obtained in the TOPS project which indicate that, for many of the sample tasks considered in the TOPS project, a simple gripper-like effector functions roughly as well as a highly dextrous anthropomorphic mechanical hand. The importance of these results, however, are limited by lack of knowledge concerning the extent to which the sample tasks studied are truly representative of the tasks to be encountered in Navy work.

Progress Report (May 91 - May 92)

During the past year, work has focussed on the testing of mechanically constrained human hands on a subset of the task boards used in the Navy TOPS project ("panel removal," "attachment to existing lift point," "clevis pin insertion," "securing an object," "rigging an existing structure," and "search and sort"). Mechanical variations in hand function were achieved by restricting degrees of freedom and/or range of motion (e.g., eliminating the use of certain fingers or joints) and/or modifying the finger compliance and surface friction.

Overall, the results of these tests showed that severely modified and constrained human hands could perform the given tasks almost as well as the normal human hand (even without much practice). In particular, only small differences in task completion time were measured between the normal human hand and the human hand modified to function as a simple gripper with minimal tactile sensitivity (achieved by restricting the hand to use of only the basal joints in the thumb and index finger and covering the finger surfaces with hard plastic overlaid with material having approximately fingerlike compliance). It should also be noted, however, that when the effector consisted of the normal human hand manipulating an ordinary pair of pliers, completion times tended to increase for all tasks except "search and sort", even when the acting surfaces of the pliers were covered with compliant material.

We have not yet been able to make detailed quantitative comparisons between our results and those obtained in the TOPS project, and such comparisons would be confounded by differences in the quality of visual information available in the two cases (whereas in the typical TOPS test, the objects were underwater and visual information was achieved via the visual channel in the teleoperator system, in our tests the objects were in air and could be viewed directly). Nevertheless, it appears that, for most of the tasks considered, the results obtained with all of our hand configurations (both normal and constrained) are roughly comparable to those obtained by the TOPS diver and much superior to those obtained with either the WSM or the Sarcos telerobot effector. The only task considered for which this was not the case was "panel removal"; for this task, all systems had roughly (within a factor of 2) completion times.

In general, the results obtained both in the TOPS tests and in our tests with the TOPS task boards suggests that most of these tasks can be performed as well with very crude, simplified, and minimally sensitive hands as with highly dextrous, sensitive, human or human-like hands.

Assuming that these preliminary results hold up in the face of further tests and further analysis of test results (to be performed over the next few months), we regard the most crucial question for Navy planning to be the following:

To what extent do the tasks selected for the TOPS tests truly reflect the tasks required for envisioned Navy work?

We know (from our own experiments, as well as from simple reasoning) that there are many tasks for which performance with our simulated-gripper hands is much worse than the performance obtained with our normal human hands. However, we do not know the extent to which these other, more demanding tasks, are relevant to Navy needs.
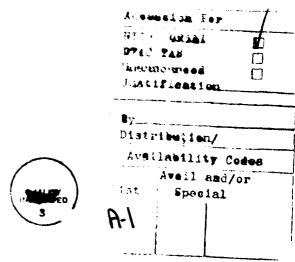
Planned Work for Remainder of Grant (May 92 - Sept 92)

Research performed during the reminder of this grant (we are requesting in a separate document an extension to Sept 30, 1992, without additional funds) will focus on (1) Verifying the above results by means of further experiments and analyses; (2) Exploring performance on the TOPS tasks using human hands that are degraded by means of anesthetics rather than mechanical constraints; (3) Preparing a report summarizing the results of our work on this grant; and (4) Completing a paper on the ability of the hand to discriminate between different values of compliance.

In addition, and perhaps, in the long run, most important, we intend to begin a major analysis project aimed at defining (constructing) a set of "generator tasks" which has the following properties:

(A) Knowledge of performance on this set of tasks for any given hand (human or artificial) enables one to predict performance of this hand on any other task;

(B) This set of tasks is minimal in the sense that any other set that satisfies (A) takes longer (or is more difficult) to perform.

As indicated above, improved methods for selecting sample tasks for evaluation of telerobotic manipulation systems is crucial to the development of improved systems. The proposed analysis, although it obviously cannot be completed within the financial and temporal constraints of the current grant, is essential to the upgrading of these methods. (We intend to continue this work, as well as work on the ability of the human hand to discriminate force variables, under our ONR URI grant.)

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